MASSACHUSETTS FARM

Energy

Best Management Practices for

Greenhouses

Massachusetts Farm Energy Program

Conservation • Efficiency • Renewables

Massachusetts Farm

Energy Best Management Practices

Berkshire-Pioneer Resource Conservation & Development Area
GDS Associates
Massachusetts Department of Agricultural Resources
Massachusetts Farm Energy Program
USDA Natural Resources Conservation Service

Amherst, Massachusetts · 2010

MASSACHUSETTS FARM ENERGY GUIDES BY FARM SECTOR

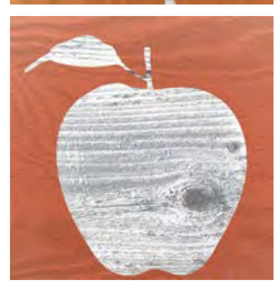
Please note that this guide is part of a series of farm energy Best Management Practice guides available for the following sectors and topic areas:

Dairy Farms

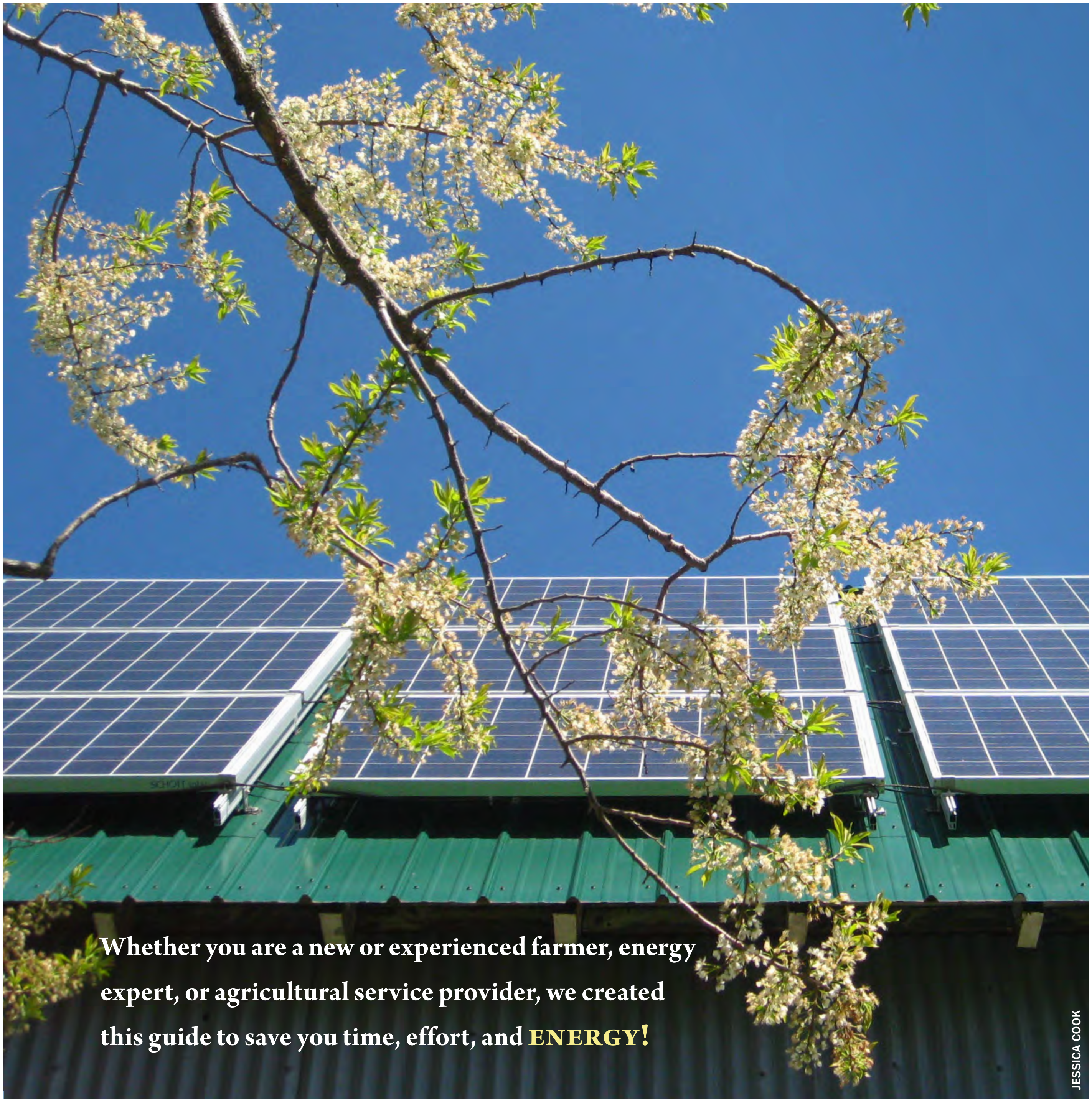
Greenhouses

Maple Sugaring

Orchards & Vegetable Farms



Renewable Energy


Whether you are a new or experienced farmer, energy expert, or agricultural service provider, we created this guide to save you time, effort, and ENERGY!
JESSICA COOK

Welcome to the Massachusetts Farm Energy Best Management Practices Guide

Practical solutions & entry points

This guide is about practical steps you can take immediately, with a focus on the most common and cost-effective equipment upgades and systems currently available for farms in our region.

For farmers who are managing a constant flow of weather events and day-to-day business needs, we offer an entry point to on-farm energy savings and renewable systems that make use of the technical skills and systems-thinking of our local community.

Thinking of systems from the start

The farm energy guide is organized by sector, focusing on retrofits that work for existing farming operations. However, farmers can also apply the guidance provided in these pages to incorporate energy issues into the planning and initial design stages of new agricultural businesses.

There is an increasing amount of interest in energy amongst the state's farmers, and examples in this guide can provide a launchpad for more innovative energy systems in the future.

The goals of these energy best management practices are to:

Strengthen farm businesses by lowering operating costs, reducing labor, and increasing profits over time.

Reduce environmental impacts of the agricultural sector, with a focus on lowering carbon emissions.

Help farms transition into the next generation by utilizing efficient technology and forward-thinking design.


JESSICA COOK

Sometimes you just need a place to start—
—based on good information and solid economics.

We hope that by breaking things down by process or technology—looking at average savings and commonly recommended measures—we offer readers a place to start their projects.

We know for many farms economic feasibility is the first question when it comes to on-farm energy projects—is the investment worthwhile?

We have highlighted estimated payback periods in the following pages, identifying the number of years an upgrade will take to pay for itself.

While we calculate the dollar savings in fossil fuels or other energy sources, it's important for you to consider other benefits on the farm, such as reduced farm labor or increased sales resulting from greener systems.

The examples in this guide are drawn from real life, based on averages across farms in Massachusetts who have worked with MFEP, so payback numbers are directly applicable to the scale of farms in our region.

Encouraging climate and resources

Forward-thinking energy policies at the state level have combined with supportive agencies and utility programs, financial incentives, and good partners to provide fertile ground for farm energy projects in Massachusetts.

We are enthusiastic about the energy future of the agricultural community in our region, and acknowledge the motivated farmers who are open to sharing their experiences, willing auditors, and proactive installers who are getting projects up and running.

We encourage you to take advantage of these key resources to move ahead with your own farm energy project!

— the Massachusetts Farm Energy Program team

Acknowledgements

This farm energy best management practices guide was compiled and written by GDS Associates, Inc. (GDS) for the Massachusetts Farm Energy Program (MFEP). Specifications and recommendations in this document are based on industry-specific research and informed by the audits and projects implemented with the assistance of the Massachusetts Farm Energy Program (MFEP) between 2008 and 2010.

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Introduction

The *Massachusetts Farm Energy Best Management Practices Guide* provides the Commonwealth's agricultural community with resources and methods to reduce energy use and produce renewable energy on farms. These recommended on-farm energy upgrades improve farm viability and minimize the environmental impact of the agricultural industry in Massachusetts by reducing energy consumption, operating costs, emissions, and dependence on fossil fuels.

These guides focus on conventional energy best management practices (BMPs) - cost-effective practices that offer significant environmental and economic benefits - for the four primary agricultural sectors represented in the Commonwealth: greenhouses, dairy farms, orchards and vegetable farms, and maple sugaring. It also covers considerations for on-farm renewable energy options, including wind, solar thermal, solar photovoltaic and biomass.

This document aims to be a practical resource for farmers and service providers alike, organized to help readers understand farm energy use, evaluate potential equipment upgrades, and prioritize energy efficiency and renewable energy opportunities. The information in this guide can also be used to inform policy, technical assistance programs, and government agency and public utility cost-share programs for energy efficiency and renewable energy on farms.

The information in this guide is based on industry-specific research and Massachusetts Farm Energy Program (MFEP) data from more than fifty energy projects implemented between 2008 and 2010. For areas not covered in this document, additional information can be found by contacting the Massachusetts Farm Energy Program (MFEP).

Environmental Impact of Energy Use

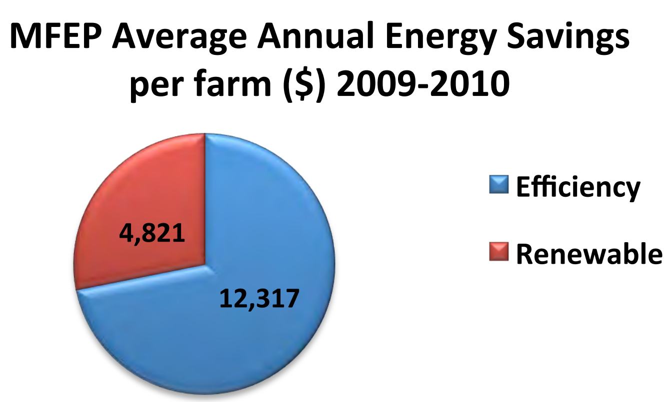
Energy conservation and renewable energy systems on farms can help reduce the use of fossil fuels and related greenhouse gas emissions, and mitigate the contribution of Massachusetts agriculture to point-source pollution and global climate change. Massachusetts' farmers can set an example for other industries in the region by making viable business decisions that improve operations and profitability while reducing negative environmental impacts of "business as usual". MFEP's experience illustrates farms' improved environmental performance - through reduced carbon dioxide emissions – as a result of energy efficiency and renewable projects.

Economic Benefits of Energy Savings

New England farmers pay 23-56% higher rates for energy resources than the U.S. average. As farmers identify the source of their energy demand and make improvements to their systems, they can reduce their dependence on fossil fuels and improve their bottom line. MFEP's work with has assisted farmers do exactly that, thus having a direct impact on the financial viability of many Massachusetts farms.

The average net income of a Massachusetts farmer is just over $12,000 according to the National Agricultural Statistics Service. At the same time, average annual energy savings from farm energy efficiency projects facilitated through MFEP average out at $12,000 per farm (see chart below), thus making energy efficiency improvements a sound business decision that can have a significant impact on overall farm viability. The economic benefit of these savings is further multiplied as farmers reinvest in the local economy in a variety of ways as they maintain and build their businesses.

It is important to note that energy projects results in different rates of financial returns for farms, either through reduced energy use or offsetting fossil fuel use with renewable energy. Renewable projects can work out favorably in terms of overall return on investment for farms, particularly with the support of grant and payment programs. However, efficiency projects save 2.5 times more energy on average than renewable systems generate per dollar invested.



About the Massachusetts Farm Energy Program

What is the Massachusetts Farm Energy Program?

The Massachusetts Farm Energy Program (MFEP) is a full-service program for technical and financial assistance for farmers and agricultural businesses. It is a statewide collaborative effort, bringing together federal, state, industry, and private support to streamline resources available to Massachusetts farmers in order to 1) increase on-farm energy conservation and efficiency, 2) promote alternative and renewable energy strategies for on-farm energy generation, 3) improve farm viability by reducing energy consumption and costs, and 4) reduce agricultural greenhouse gas emissions. MFEP is a joint project between the following partners:

- Massachusetts Department of Agricultural Resources (MDAR) www.mass.gov/agr
- USDA – Natural Resources Conservation Service (NRCS) www.ma.nrcs.usda.gov
- Berkshire-Pioneer Resource Conservation & Development Area (BPRC&D) www.berkshirepioneerrcd.org

MFEP has offered a range of services to the farming community, including technical assistance, audits and consultations, financial incentives, and facilitation to leverage funds to bring projects from initial concept to implementation.

Why MFEP?

Electricity and fossil fuel costs have increased by approximately 30% in the last few years. The impact on farms has meant a dramatic increase in costs related to power, refrigeration, heating, ventilation, lighting, transportation, fertilizer, and feed. Rising energy costs reduce profit margins for all farmers and directly threaten the viability of farms across the Commonwealth.

The agricultural community has not maximized energy savings in part due to challenges in navigating an ever-changing landscape of support programs. MFEP streamlines these resources and provides direct technical assistance through energy audits, renewable energy assessments, and incentives for implementation of audit recommendations, including those recommended by public utility programs. As a result of complex partnerships between farm business owners, government agencies, for-profit practitioners, and public programs – farm energy upgrades are contributing to the region's environmental goals and stability and resilience of our agricultural communities.

Best Management Practices for Greenhouses

In this section you will find the following best practices:

- Electronic Temperature Controls
- High Efficiency Refrigeration including Heat Recovery
- Higher Efficiency Heating Systems
- Energy Efficient Lighting
- Poly Film and Rigid Glazing
- Sidewall / Foundation Wall and Endwall Insulation
- Thermal Blankets / Energy Screens
- Under Bench / Root Zone Heating
- Natural Ventilation / Efficient Mechanical Ventilation

Nursery, greenhouses, floriculture, and sod make up the largest agricultural sector in Massachusetts, with 814 farms and an annual commodity worth $169,167,000 according to 2007 census data.

The first step in proper energy management is to learn about best practices. This handbook will help you consider potential options and whether these options may be applicable to your greenhouse.

The second step is to consider an energy audit. An energy audit can help determine which energy efficiency measures, based on the existing conditions and equipment of your facility, can be most useful. The audit will point out the major energy users and ways to save money through energy conservation and efficiency.

Energy is the second largest cost for greenhouses behind labor. For a typical greenhouse, about 70-80% is for heating and 10-15% is for electric consumption. Minimizing energy use for heating should be the first priority followed by ventilation and energy efficient lighting. Consider the following recommendations and refer to the appropriate sections for more information.

Heating

- Conserve energy by reducing the amount of heat that escapes
  - Keep doors closed, weather strip doors, lubricate louvers, repair broken glass
  - Use sidewall and endwall insulation, use poly with an infrared inhibitor
  - Install a thermal blanket to keep heat in at night
- Use energy efficiently for heating
  - Use under bench heating
  - Replace old heating systems with a higher efficiency system
  - Use an electronic temperature control to precisely control temperature setpoint

Electric

- Reduce energy required for ventilation
  - Consider using natural ventilation when retrofitting or for new greenhouse designs
  - Use efficient fans for mechanical ventilation
- If supplemental lighting is used, use efficient and well-positioned light fixtures that have a high efficacy [lumens/watt] and promote even light distribution

Due to the wide range of greenhouses, energy use and potential savings can vary greatly. An example of two similarly sized greenhouses is shown below using energy modeling to show potential savings. The information is based on weather data in Massachusetts. Although this may illustrate a dramatic upgrade, it helps show the huge variability in heating costs for greenhouses and the potential for savings.

	Greenhouse 1 – Poorly Designed and Operated	**Greenhouse 2 – Well Designed and Operated**
Type	Gabled	Gabled
Dimensions	35' x 100'	35' x 100'
Floor Material	Bare dirt	Concrete
Walls - Side wall	Glass, single	Poly, Double, IR inhibited
Walls - Knee walls	Framed, plywood, no insulation	Poly, Double, IR inhibited
Heating	Forced Air	Under bench
Heater Seasonable Efficiency	0.68	0.9
Perimeter Insulation	None	2 inches of foam insulation
Infiltration rate (air exchanges per hour)	High - 2.0	Low - 0.5
Thermal blanket	No	Yes, 65% shade, semi-porous
Elect. Temp. Controls	No	Yes
Precise climate control	Poorly controlled	Well controlled

Annual Energy Usage	**20,075 gallons of LP***	**2,712 gallons of LP***
Cost	**$40,149**	**$5,400**
% savings	**-----**	**86%**

*For conversion purposes of different fuel sources, 1 gallon of LP = 91,500 BTU; 1 gallon of Fuel Oil = 138,500 BTU; 1 therm = 100,000 BTU.

It is possible to reduce energy usage by 86% -- from 5.7 gallons to 0.8 gallons LP/sqft/year -- by making upgrades to achieve a well-designed and operated greenhouse.

Best Practice

Electronic Temperature Controls

At a Glance:

- 3-12% energy savings
- Payback ranges typically between 2 – 5 years
- Optimal growing conditions can be programmed
- Heating and ventilation periods are staged
- Automating greenhouse operations can save labor

Description of Best Practice

Electronic temperature controls automatically operate heating and ventilation equipment depending on the heating and ventilation required by the greenhouse. Thermal and shade curtains, irrigation and misting systems, as well as supplemental lighting, may be tied into a computerized control system. Components of an electronic temperature control system include a centralized computer control box as well as thermostats throughout the growing space. Other components may include a weather station, photo sensors, humidistats, carbon dioxide sensors, controls for misting and irrigation applications, as well as alarm alerts.

Benefits:

- Saves energy by reducing the runtime of equipment
- One thermostat is used rather than two separate thermostats for the heating and ventilation systems. Electronic controls program ventilation and heating equipment so they are not running at the same time
- Allows for small temperature differentials for turning a device on and off, which maintains an even temperature in the greenhouse over time

Applications & Limitations

Electronic temperature controls can be used to regulate temperature throughout the greenhouse growing season. There are several advantages to controlling temperature utilizing an automated control system:

- Temperatures can be programmed for the entire growing season and adjusted as needed
- Automates differential temperature control (DIF) between day and night, allowing a lower temperature setting for nighttime, reducing nighttime energy consumption
- Records ambient and greenhouse temperature data for future reference

Heating and ventilation controls are the basic mechanisms of greenhouse control systems. Systems can be designed to use an electronic temperature control to efficiently maximize growing conditions by:

- Working with a weather station, which anticipates ambient temperature, wind speed and day length changes and automatically adjusts heating, ventilation, lighting, and curtain needs appropriately, rather than being based on sensor readings only
- Allowing for automation of greenhouse humidity, carbon dioxide, supplemental lighting, thermal curtain operation, and irrigation applications
- Providing alarm alerts via phone, email or other signal which may indicate heating, ventilation or other system failure
- Recording data to allow growers to learn from growing conditions from season to season
- Automatically staging different heating and ventilation mechanisms so that heating is not running at the same time as ventilation, and root zone heating takes priority over overhead air heating

Manufacturers of greenhouse control systems will typically offer to train the grower on how to program and optimize their operation, or they can custom program the control system to meet the grower's needs. A computer control will be effective if programmed appropriately and monitored to ensure programmed performance.

Minimum Standards & Recommendations

It is recommended to choose electronic temperature controllers with 1°F temperature differentials as they are optimal and allow more precise control versus controls with higher temperature differentials. (A mechanical thermostat can have a differential of 4° to 8°F.) It is recommended to set a deadband (neutral zone) between heating and ventilation operations during winter and spring. For example, if the desired greenhouse temperature is 65°F, it may be optimal to set the heating/ventilation set points to 62°F/69°F respectively, rather than 63°F/67°F.[i] A higher temperature difference for dead band settings will ensure heating and ventilation equipment are not running at the same time, and may allow the greenhouse to capture more heat from the sun.

Manage override controls carefully. Some control systems do not automatically reset when override has been set. For example, a thermal curtain may not close for the evening or a programmed thermostat setting may not register because a system is in override mode.

Using differential temperature control (DIF) between night and day settings may optimize energy consumption. However, producers should research appropriate growing temperatures and monitor conditions carefully. Lower temperatures may reduce plant growth rates, extending the overall heating season, and may also increase insect and disease problems.

To ensure accurate temperature readings, it is recommended to place sensors near plant height/location and not on endwalls.

Maintenance

It is important to properly maintain the control system per manufacturer recommendations. Maintenance maximizes performance of electronic environmental controls. Sensors, including thermostats, humidistats or carbon dioxide sensors should be calibrated each year and properly cleaned. A dirty thermostat will not sense temperatures accurately. Control panel(s) may benefit from vacuum cleaning.

Energy Savings

If differential temperature control (DIF) is utilized between night and day, it has the potential to save about 3% of heating fuel needs for each 1°F the nighttime temperature is reduced. Typical annual heating fuel savings associated with DIF in greenhouses is 5%.

Total energy savings will depend on system components and existing controls utilized in the greenhouse. A 1998 study out of Saint Hyacinthe, Quebec in Canada found an average of 12.5% annual heating energy savings associated with using electronic temperature controls.[ii]

Installing an electronic temperature control with a 1°F accuracy in a 30'x100' greenhouse could save up to 500 gallons of fuel oil/year over mechanical controls.[iii] Due to the large range of greenhouses, an energy audit is highly recommended before considering any major upgrades.

Environmental Impact & Benefits

The fuel savings achieved by implementing an electronic temperature control will result in a reduction of greenhouse gas (GHG) emissions, reducing the environmental footprint of the greenhouse.

Economic Benefit

Monetary Value of All Benefits

Energy cost savings provided by using electronic temperature controls will be based on length of the heating season, temperature settings, and components controlled.

Estimated Cost of Implementation

Depending on the complexity of the system, environmental controller costs typically range from $500 up to $2,000. Typical cost of an individual greenhouse controller is $1,000.

Typical Payback

Payback ranges for electronic thermostat controls are typically within 2 to 5 years.

Best Practices for Greenhouses - Refrigeration

Technology

High Efficiency Refrigeration Including Heat Recovery

At a Glance:

- High efficiency refrigerators use 20-35% less energy than a standard modern refrigerator and 60% less energy than a 20-year old refrigeration unit
- High efficiency refrigeration and/or heat recovery will often pay back on investment within 2.5 – 5 years.

Source: www.awrco.com

Description of Best Practice

Solid-door, walk-in, and warehouse refrigeration is often used in the greenhouse industry for storage of produce, plants, cuttings, and floral products, in addition to refrigerated glass-case storage for flower shop displays. Modern, high efficiency refrigerators use about 60% less electricity than 20-year old refrigeration units.

Components of High Efficiency Refrigeration:

- *Energy Efficient Lighting*. T-8 and T-5 fluorescent lighting have proven to use about 75% less energy than incandescent and 50% less energy than High Intensity Discharge (HID) lighting. LED lighting performs well at refrigeration temperatures (13° to 77°F). LED lighting lasts up to 3 times as long as HID and T8 fluorescent lighting and uses about one-third the energy of standard HID fixtures and about half the energy of T8 fluorescent fixtures.
- *Energy Efficient Compressors*. Scroll compressors, linear compressors, and the addition of electronic expansion valves are all ways to achieve superior compressor energy efficiency when compared to older reciprocating compressors.
- *High Efficiency Fan Motors*. Removing heat from the compressor system has become more efficient with use of electronically-commutated motors (ECM) and improved fan design.
- *Insulation and Heat Loss Design*. Gaskets, thicker wall insulation, foam-in-place rather than fiber insulation, double or triple glass doors and low-E glass all improve efficiency.
- *Improved Defrost Methods*. Heat recovery from refrigerant gas may be used in modern defrost methods to melt freezer frost as well as to evaporate condensate from refrigeration defrost. Defrost controls have replaced standard timers, and operate according to the temperature of the unit allowing complete defrost only when needed.
- *Heat Recovery Condensation Control*. Rather than electric resistance heat, heat recovery from refrigerant gas can be used under the surface of door openings and around the door seal to prevent sweating.
- *Drain Maintenance.* Gaskets and seals added to condensate drains can minimize infiltration heat loss.
- *Heat Recovery for Space or Water heating*. Utilize heat from refrigeration compressors to pre-heat water and/or provide space heating.

Best Practices for Greenhouses - Refrigeration

Application & Limitations

The operating cost of refrigerators and freezers is often greater than the up-front cost of their purchase. It is important to consider a refrigerator or freezer's cost-to-operate when making a decision to purchase. Although a model may be half the price of a new high efficiency model, the less efficient model's operating cost may be twice as expensive, resulting in a much higher life cycle cost.

Not all models are easy or cost-effective to retrofit with the recommended efficiency upgrades. Considering that the life of a refrigerator or freezer is about 10 years, it is recommended to weigh retrofit costs against the cost of purchasing a new energy efficient model.

Minimum Standards & Recommendations

When purchasing a new commercial refrigerator or freezer model, choose from those qualified to meet ENERGY STAR requirements. ENERGY STAR models use 20% less energy than standard models, and come with an ECM evaporator and condenser fan motors as standard. ENERGY STAR models meet the minimum efficiency standards set by the National Appliance Energy Conservation Acts (NAECA). Each model of refrigerator or freezer will vary in operating costs, whether it is labeled as ENERGY STAR or not, so it is recommended to compare the costs of running each unit when making a purchase.

Insulation is critical for refrigerators. Since 2009, walk-in coolers are required to have an R-value of R-26 for coolers and R-32 for freezers. Choose a walk-in cooler with even higher insulation and with extruded polystyrene for walls, ceiling, and floors instead of polyurethane for better long term performance. Purchasing refrigerators that are ENERGY STAR certified will ensure that refrigerators have proper insulation values.

If replacing an older reciprocating compressor, it is recommended to install a new compressor with a high efficiency digitally controlled scroll compressor. These compressors can have an energy efficiency ratio (EER) of 11 compared to an old reciprocating compressor with an EER of 6 to 8.

It is recommended to complete annual or semi-annual maintenance in order to maintain the efficiency and increase the longevity of refrigeration equipment. A refrigeration professional will often have the required equipment, such as appropriate lubricants and metering devices, to perform routine maintenance. Refrigeration maintenance includes cleaning condenser coils (possibly pressure cleaning and degreasing), cleaning condensate lines, checking gaskets, wiring, and refrigerant levels, monitoring thermostat operation and temperature cycling, and checking defrosting mechanisms.

Heat recovery for space or water heating is recommended at facilities that use warehouse-size refrigeration and have space heating needs. Heat can be recovered from the condenser units and cycled to in-floor heating systems or through heat exchangers into forced air heating systems.

Best Practices for Greenhouses - Refrigeration

Energy efficiency of space and water heating using heat recovery from refrigeration compressors will depend on the demand for hot water or space heating. Heat recovery for water heating makes the most sense in applications where there is consistent hot water demand throughout the year. Heat dispelled from air cooled refrigeration condensers can be used for space heating when the unit is located indoors; however, heat recovery is not typically used in traditional space heating systems.

Environmental Impact and Benefits

The energy savings and offset of electrical production achieved by installing high efficiency refrigeration and/or heat recovery will result in a reduction of greenhouse gas (GHG) emissions, reducing the environmental footprint of the operation.

Energy Savings

Data has shown energy savings ranging from 9% to 44%, comparing older, less efficient with high efficiency refrigeration models. For example, the average of 72-cubic foot refrigerator models sampled in Canada in 2003 consumed about 6,300 kWh annually, while a high efficiency refrigerator of the same size is estimated to consume 4,292 kWh, a 31% energy savings.[iv]

Economic Benefit

Estimated cost of implementation:

High efficiency, ENERGY STAR refrigerators and freezers are more expensive, but will provide annual savings over standard efficiency models. Prices will range depending on location, size and application. As an example, an ENERGY STAR, solid-door 46-cubic foot refrigerator was found to range in price from $3,150 to $5,900. Glass door ENERGY STAR rated refrigerators of the same size adds $1,200 to $2,000 to the total cost.

Walk-in refrigerators and coolers may cost well over $10,000, and warehouse refrigeration prices will vary greatly depending on size, building structure, and refrigeration components. Rather than upgrade to an entirely new walk-in or warehouse refrigeration system, it may be economical to retrofit large cooling systems with energy efficient measures. Refer to the *Best Practices for Orchards and Vegetable Farms: High Efficiency Refrigeration Including Heat Recovery* for specific energy efficiency retrofit recommendations.

Heat recovery units for water heating can range from $3,000 to $5,000 depending on the size and installation requirements. Heat recovery for space heating costs will vary depending on the need for heat exchange equipment and control methods to incorporate into the space heating system.

Typical Payback:

According to the US EPA and DOE, ENERGY STAR commercial refrigerators and freezers can result in energy savings as high as 35% and a payback as low as 1.3 years compared to standard models.[v]

Best Practices for Greenhouses - Refrigeration

An economic analysis of the payback on refrigeration and freezer retrofits found the following energy efficiency upgrades have the potential for a payback of less than 2.5 years based on the application[vi]:

- electronically commutated motors (ECM) for brushless DC motors
- evaporator fans, or condenser motors
- high efficiency compressors
- variable speed compressors
- hot gas anti-sweat methods
- high efficiency fan blades.

Heat recovery for water heating needed throughout the year will also have a typical payback of less than 2.5 years.

Best Practices for Greenhouses – Heating Systems

Best Practice

Higher Efficiency Heating Systems

At a Glance:

- Choose heating systems with an efficiency greater than 90% (for gas or propane).
- Choose condensing or direct-vent type heaters.
- Perform regular efficiency tests and maintenance to keep heaters running efficiently and increase

Description of Best Practice

Greenhouse air temperature is critical for plant growth, disease control, and plant survival. Solar gain provides the majority of heat during the day, but supplemental heat is required during cold nights and overcast days. There are several types of heaters that can be used in greenhouses.

Standard unit heaters have thermal efficiencies between 70-80%, but the seasonal efficiency may be lower due to the use of heated air for combustion or heated air escaping out of the flue when the heater is not firing. High efficiency gas unit heaters have an efficiency of 90% or greater, and separated combustion fuel oil unit heaters have efficiencies up to 82%. LP and natural gas unit heaters are available in condensing type units that have an extra heat exchanger which removes additional heat from the exhaust air before it is emitted.

There are five different types of unit heaters: gravity-vented, power-vented, separated combustion, condensing, and direct-vent. Only gravity vented, power vented, and separated combustion unit heaters are available for fuel oil, given its combustion properties. The chart below gives the thermal efficiency and seasonal efficiency of different types of unit heaters[vii]:

Unit Heater Type	Fuel Type*	Thermal Efficiency	Seasonal Efficiency
Gravity-Vented	LP, NG, FO	80%	65%
Power-Vented	LP, NG, FO	80%	78%
Separated Combustion	LP, NG, FO	82%	80%
Condensing	LP, NG	93%	91%
Direct-Vent	LP, NG	99%	92%

*LP is liquid petroleum (propane), NG is natural gas, FO is fuel oil.

Best Practices for Greenhouses – Heating Systems

High efficiency condensing unit heaters have an additional heat exchanger compared to separated combustion units. The additional heat exchanger extracts more heat from the exhaust air and increases the efficiency by about 10%. Direct-vent heaters discharge all of the products of combustion into the greenhouse, providing about 99% thermal efficiency. However, direct-vent heaters can release harmful pollutants such as carbon dioxide, sulfur dioxide, and water vapor (potentially increasing the indoor relative humidity up to 90% in winter) and can result in poor indoor air quality. As a result, they need to be carefully monitored and coupled with oxygen intake which reduces the seasonal efficiency to approximately 92%.

Application & Limitations

High efficiency unit heaters are most applicable in greenhouses that have a long heating season (spring, fall, and winter). Replacing an existing working heater with a new high efficiency heater may not be cost-effective for greenhouses with limited heating needs, but should be considered if the existing heater needs to be replaced due to imminent failure. An energy audit can help determine if replacing an existing heater with a new high efficient heater is cost-effective.

Biomass can also be used to provide heat for greenhouses. Please see the renewable energy best practices for biomass options.

Minimum Standards & Recommendations

Purchase furnaces with a high seasonal efficiency to reduce fuel usage.

To minimize issues with new high efficiency units and to ensure validity of the warranty, have the unit installed by a professional. Most problems with the operation of high efficiency heating systems have resulted from improper installation.

Maintenance

It is recommended to perform proper maintenance practices to increase the efficiency of the heater, reduce energy consumption, and lower operating costs. The following are recommendations:

- Have your heater cleaned and adjusted before each heating season by a competent service person to keep heater operating at peak efficiency and to extend the life of the equipment. The efficiency of a heating system can be improved by 5% with proper service.
- Clean soot deposit from exterior heat exchanger surfaces.
- Have a combustion efficiency test performed. This test takes less than 10 minutes and can help indicate any problems.
- Check to make sure adequate air is entering the heater for proper combustion. If a separated combustion heater is not installed (which has a direct connection to outside air), then an air supply from a pipe or louver should provide the required amount of air.

Other recommendations to increase heater efficiency include:

- Focus on conservation practices to reduce annual runtime of heater.
- Lock in fuel prices in August when fuel prices are typically lower.
- Install a climate control system to manage heating and cooling systems and use electronic temperature controls with a +/- 1°F differential
- Use horizontal air flow (HAF) fans to provide more uniform growing temperatures in the greenhouse
- Consider under-bench heat. This can allow air temperature to be set 5° to 15°F lower.

(Check other best practices sections for more information relating to specific practices listed above.)

Energy Savings

Energy savings will vary based on the type of heater installed, the greenhouse design, and temperature set-points. Higher efficiency unit heaters reduce energy consumption and fuel costs. A 28-foot by 100-foot Quonset style IR-poly film greenhouse can save 149 gallons of fuel oil or 227 gallons of LP in a year and increase the thermal efficiency of overhead heating from 78% to 82%.[1]

Environmental Impact & Other Benefits

Proper maintenance will help maintain efficient combustion, reduce fuel usage and ensure complete combustion while limiting harmful pollutants from being released.

The fuel savings achieved by installing a high efficiency heater system and properly maintaining it will result in a reduction of greenhouse gas (GHG) emissions, reducing the environmental footprint of the greenhouse

Economic Benefit

High efficiency unit heaters range in price based on the size of the unit and the manufacturer. Incremental costs for a high efficiency heater compared to a standard power-vented unit heater with a similar output, range from approximately $600 to $1,500. Payback for a unit heater retrofit, 78% to 82% thermal efficiency, can range from 1.6 to 4 years, based on the fuel oil price of $2.50 per gallon and a 28-foot by 100-foot Quonset style IR-poly film greenhouse. Payback for a gas unit heater retrofit from 78% to 92% thermal efficiency could be less than one or two heating seasons for a similar style house, based on LP priced at $2.00 per gallon.

[1] Based on modeled heat loss data for an IR poly film greenhouse as described, with weather data from Worcester, MA.

Best Practices for Greenhouses - Lighting

Best Practice

Energy Efficient Lighting

At a Glance:

- Install new HID fixtures with electronic ballasts for lower operating and maintenance costs and less lumen depreciation
- High pressure sodium is currently the most efficient source of lighting
- Be sure to dispose of bulbs properly, visit: epa.gov/bulbrecycling

Description of Best Practices

Supplemental lighting can boost plant growth and extend the growing season. Using efficient lighting that provides the correct wavelength is essential to keep operating costs low and provide the necessary light a plant needs for photosynthesis. For more information about lighting for shops, packing rooms, retail, offices, or other facilities besides greenhouses, please refer to the lighting section in the *Best Practices for Orchards and Vegetables.*

High Intensity Discharge (HID) Fixtures with Electronic Ballasts

HID fixtures are the most common type of greenhouse lighting, and include high pressure sodium (HPS) and metal halide. Most current greenhouse lighting uses HID lamps with magnetic ballasts. (Ballasts are used to provide the proper starting and operating electrical conditions to power a lamp.) Electronic ballasts have been used for fluorescent lights for many years but have more recently been designed and used for HID lighting. There are many benefits to using electronic ballasts compared to magnetic[viii]:

Benefits of Electronic Ballasts:

- Lower operating and maintenance costs
  - Higher efficacy [lumens/watt], meaning more light for less energy
  - Longer lamp life
- More consistent light output (less depreciation as the bulb ages)
  - More consistent light output means fewer wasted lumens and greater energy savings
- Enhanced color control
- Fewer fixtures needed to light the same amount of space
- Delivers 35% more light than magnetic ballasts
- Potential energy savings of more than 40% per year
- Dimming capabilities – allows facilities to take advantage of photosensors, ideal for greenhouses that use an automated control system

High Pressure Sodium (HPS)

High pressure sodium (HPS) is the most energy efficient lamp for greenhouse lighting and is suitable for most plant types including vegetables, cut flowers, potted plants, and bedding plants. About 30% of the electrical energy input is converted into photosynthetically active radiation (PAR), quantified as μmol-photons/m^2/second, which is the spectral range of solar radiation (from 400 to 700 nm) that photosynthetic organisms are able to use. The majority of the light energy from HPS is near 700 nm, the wavelength that plants need. As a result, HPS fixtures result in excellent plant growth and development, provided that the plants receive enough natural light. (A greenhouse that is not shaded from the sun will normally provide adequate natural light.) If growing indoors or in areas with minimal natural light, metal halides can be used in combination with HPS to provide the entire spectrum for light.

Metal Halide

Metal halides provide a white/bluish light (spectrum close to sunlight) and promote seedling and strong vegetative growth. They can be combined to work in tandem with HPS lamps for particular applications such as growth rooms, without sunlight, where a complete light spectrum is required for balanced plant growth.[ix] Best practice is to install pulse start metal halides (PSMH) with electronic ballasts. PSMH offer the following benefits compared to conventional probe metal halides:

- Higher efficacy [lumens/watt]
- 25% less energy for similar light outputs
- Less lumen depreciation as bulbs age
- Longer lamp life, meaning reduced maintenance costs
- Quicker startup
- Better cold starting capability (as low as -40°F)

Reflectors

Reflectors can play a critical role in a well-designed lighting system that promotes uniform growth. Reflectors should be designed to reflect the light in the desired direction. The efficiency of a reflector is determined by its shape, reflecting angle, and the emission of total light quantity within that angle. Lighting design experts, who have the necessary data files from manufacturers, should be consulted about light output and direction based on the reflectors. The consultants will use computer software to provide an optimal, uniform light design. They should be made aware of the color spectrum needed for plant growth, as color spectrum information is available and can be incorporated into a lighting analysis.

Light Emitting Diodes (LEDs)

Source: http://astore.amazon.com/locksmithlock-20/images/B001MVWYZA

The next frontier of lighting for plant growth is the use of LEDs. LEDs can be designed to emit only the wavelength of light needed for plant growth (PAR wavelength). LED lights are currently very expensive compared to HID lamps and are usually limited for use in smaller greenhouses and indoor plant growth due to their limited light output and high cost. There is a lot of research being done on LEDs and the next generation of new technology is continually being released. Be sure to talk to a lighting expert about what is most current before deciding to use LEDs for large scale greenhouse projects. With more research and development and market adoption, LEDs will eventually provide similar light levels as HID lamps, use less energy, and have a longer bulb life.

Application & Limitations

Lighting upgrades are applicable in most cases. If the light has minimal usage, upgrading may provide limited savings. If fluorescent lighting needs to be replaced anyway, the potential savings of purchasing fixtures with electronic ballasts time versus magnetic typically outweighs the incremental cost of the electronic ballast hardware. Also, if HID fixtures have been recently installed with magnetic ballasts, replacing new HID fixtures may not be an economical decision.

Best Practices for Greenhouses - Lighting

Minimum Standards & Recommendations

Be sure to follow all local electrical codes. Greenhouse environments are humid and may be corrosive. Verify that lighting housing, caps, and reflectors are corrosion protected and suitable for greenhouse conditions. An IP (Ingress Protection) rating of 66 is recommended. Using these fixtures will prevent corrosion, reduce failure from moisture and dirt, and allow for easier cleaning and upkeep.

Install in accordance with national best practices in lighting design (such as IESNA recommended practices) as well as spectra necessary for proper plant growth according to plant variety. Pay attention to recommended mounting heights, as some LED grow lighting works best just a foot or two above plant height.

If considering LEDs, it is recommended to purchase fixtures that meet the IESNA LM-79 and LM-80 standards. This is a third party test that will ensure the LED operates as stated. To verify marketing claims, visit the U.S. Department of Energy – sponsored Lighting Facts website, which reports independent LED testing results: www.lightingfacts.com.

Light levels gradually change as lamps age. Be sure to change lamps as recommended per the manufacturer to ensure adequate light levels are maintained as designed.

Be sure to properly recycle all lamps as required, including all fluorescent and high intensity discharge (HID) lamps. For more information about proper recycling, visit: www.epa.gov/bulbrecycling.

Energy Savings

Lighting is a primary focus for most Massachusetts public utility energy assessments and incentive programs to help save energy. Energy savings of a fixture can be calculated by the following equation:

$$Annual\ Energy\ Savings\ [kWh] = \left[\frac{old\ [watts] - new[watts]}{1000}\right] x\ daily\ hours\ of\ use\ x\ 365\ days$$

Please Note: For a more detailed description of various types of lights and potential energy savings, please refer to the Natural Resources Conservation Service (NRCS) online lighting energy self assessment, located at: www.ruralenergy.wisc.edu.

Environmental Impact & Benefits

Installing energy efficient lighting will save energy and result in a reduction of greenhouse gas (GHG) emissions. Reducing energy use reduces the overall GHG footprint of the facility by minimizing the amount emissions released from fossil fuel power plants. New light fixtures with a longer rated life can decrease maintenance and labor costs.

Economic Benefit

The actual savings of installing new lighting can vary greatly depending on factors such as installed costs and annual hours of use. To determine a simple payback, take the estimated installed cost and divide by the annual energy savings as determined from the Annual Energy Savings equation or the online calculator (www.ruralenergy.wisc.edu). It is usually recommended to replace light fixtures when the simple payback is less than 5-7 years. Some typical costs for various fixtures are:

Light/Fixture	Cost
320 PSMH	$250
400 watt HPS	$200
1000 watt HPS	$350

Best Practices for Greenhouses – Films & Glazings

Best Practice

Poly Film & Rigid Glazing

At a Glance:

- Double glazing saves about 35% of heating costs over single-layer glazing.
- IR poly film will pay for its incremental cost in one heating season.
- Choose a glazing with a low U-value.

Description of Best Practice

Glazing, or translucent materials used for the ceilings and walls of greenhouses, will vary according to grower preference. Making the choice between glass, polycarbonate, polyethylene (poly) film, or other glazing materials will depend on cost, expected material life, installation requirements, durability, and light transmittance. Rigid glazings such as glass, acrylic and polycarbonate materials have lives which may range up to several decades long. Rigid glazings have limits to their flexibility and ability to fit a curved (Quonset-style) roof. Non-rigid glazing, or poly film, is flexible durable plastic sheeting that has a life about ¼ as long as rigid glazing. Poly film can easily be wrapped over curved or regular wall and roof support structures.

It is good practice to consider heat loss properties for both rigid glazing choices and flexible poly film. Consider a glazing's U-value, or measure of ability to transfer heat, a lower U-value is superior at retaining heat than a higher U-value. In general, all single-layer glazing materials (both rigid glazing and poly film) will have a U-value of 1.0 – 1.2.[i] Double-layer glazing will reduce this heat loss by half. Two layers of poly film, inflated with a slight air space between layers, and an inner layer having an IR inhibitor will further reduce heat loss.

Applications & Limitations

Poly Film

Poly films can be made of polyethylene, polyvinyl chloride or polyester. Poly film is flexible and can be drawn across frame materials to create a greenhouse structure. Poly film can also be used for removable wall partitions to designate heated versus non-heated greenhouse space. Poly film has a life of one to five years.

A disadvantage of standard poly film is that it is passive to long-wave infrared radiation (IR) received from the sun. IR is not visible radiation, but can be felt as heat emitted from the sun and other objects. To prevent the loss of IR heat, it is recommended to purchase films which have an IR inhibitor for the interior layer.

Rigid Glazing[x]

- **Glass** glazing may be preferred because of its excellent light transmittance. Glass glazing has several other advantages including heat resistance, minimal expansion/contraction, and longevity -- it lasts over 25 years. Disadvantages of glass are its weight and its difficulty cutting and fitting onsite. U-value of single pane glass is generally 1.13, and the U-value of double pane glass is 0.70, depending on the type of glass. Poly film can be wrapped around rigid glazing to decrease infiltration and U-value, but it will also decrease light transmittance as well.
- **Acrylic** glazing, like glass, also provides excellent light transmittance. Unlike glass, Acrylic is easy to cut and fit onsite and is relatively lightweight. Acrylic can last over 20 years, but it is subject to expansion and contraction, can be flammable and easily scratched. Acrylic U-value may range from 0.55 to 0.60.
- **Polycarbonate** comes in a variety of thicknesses and can be single, double, or triple-walled. The more walls, the lower the light transmittance. Polycarbonate can be hail-proof and bend over curved surfaces, but it can be easily scratched and is subject to expansion and contraction. Polycarbonate U-values vary according to thickness and number of walls. Consult manufacturer specifications for specific U-value per type of polycarbonate. General U-values for polycarbonate are listed in the following table.

Glazing Type	U-value
Polycarbonate, double-6mm	0.72
Polycarbonate, double-8mm	0.65
Polycarbonate, double-16mm	0.58
Polycarbonate, Triple	0.50

- **Fiberglass-reinforced plastic** glazing can be corrugated or flat and its light transmittance can be comparable to poly film. It has advantages of being relatively inexpensive compared to other types of glazing, and is considered strong and easy to cut and fit on site. Problems with fiberglass-reinforced plastic include yellowing with age and susceptibility to expansion and contraction. Fiberglass has a U-value of about 1.20, and is inferior to polycarbonate, acrylic, or glass.

Best Practices for Greenhouses – Films & Glazings

Minimum Standards & Recommendations

Work with a professional greenhouse supplier during glazing planning and installation. Improper framing and extrusions can lead to issues with expansion and contraction and cause air leakage. Existing extrusions may not fit a desired glazing type. Seal gaps to reduce overall infiltration. Compare manufacturer specifications of U-value, as these may vary by product. Consider knee-wall insulation up to bench height as well as in-ground perimeter insulation. See the *Best Practices for Greenhouses – Sidewall Insulation* for more information.

Most heat loss occurs through the ceiling of greenhouses as heat rises. Therefore, it is recommended to prioritize a low U-value ceiling glazing. If a producer had to choose between replacing a ceiling or a wall, the recommended priority would be a low U-value ceiling glazing.

Energy Savings

Energy savings will vary according to existing greenhouse glazing, layout, and heating system efficiency. Double glazing saves about 35% of heating costs over single-layer glazing. For example, a 100-foot by 28-foot gable-style glass greenhouse heated through the cold season in Massachusetts can save about 2,367 gallons of fuel oil per year by switching from single to double pane glass. The same greenhouse can save 3,415 gallons of oil annually by switching from single pane glass to triple polycarbonate or acrylic glazing.

Simply adding an IR film on the inner layer of a double layer poly installation can provide fuel savings as high as 25%, with an average savings of about 12%.

Environmental Impact & Benefits

The fuel savings achieved by installing poly film or rigid glazing will result in a reduction of greenhouse gas (GHG) emissions, reducing the environmental footprint of the greenhouse.

Economic Benefit

The additional cost for an IR film is less than $0.025/sqft, or about $60 for a 28-foot by 100-foot greenhouse. In general, the incremental cost difference of IR-poly film versus standard poly film will pay for itself within one season.

Rigid glazing payback based on energy savings is highly variable. In many cases, it is not only the U-value that is improved by changing glazing, but infiltration is also being reduced.

In the example provided above, a 28-foot by 100-foot single-pane glass greenhouse may save 3,415 gallons of fuel, or $9,220 annually with fuel oil priced at $2.70/gallon by switching to a glazing with a U-value of 0.5. Acrylic glazing may provide this U-value but costs more than twice that of triple polycarbonate glazing. It should be noted that acrylic may provide a light transmittance similar to that of glass, whereas triple polycarbonate will decrease light transmittance compared to glass. New acrylic glazing for this house may cost around $35,000 not including installation. Triple polycarbonate glazing may cost $12,500 not including installation. Depending on actual glazing and installation costs, payback may be around 5 years for acrylic and 2.5 years for triple polycarbonate.

Best Practices for Greenhouses - Insulation

Best Practice

Sidewall / Foundation Wall and Endwall Insulation

Source: www.ruralenergy.wisc.edu/

At a Glance:

- Increases wall R-value and reduces heat loss.
- More economical for new construction.
- Use 2" thick insulation with weatherproofing.

Description of Best Practice

Greenhouse heat loss can occur through all areas of the building envelope: ceiling, sidewalls, or floor. Sidewall and foundation insulation can reduce heat loss without reducing sunlight for plants. This is especially important when using under bench heating systems. Insulation with a high R-value (thermal resistance) can lower the heat loss of the facility.

Foundation wall insulation can increase soil temperature near the sidewall up to 10°F during winter. Insulation can be installed either on the inside or outside of the foundation. Insulated and sealed door openings can also reduce greenhouse heat loss.

Application & Limitations

The best time to install foundation wall insulation is during construction. It is often not economically feasible to add foundation wall insulation to existing structures. Sidewall and endwall insulation can be added to a greenhouse during construction or as a retrofit measure.

Facilities should also consider insulating the north walls of greenhouses. In climates with sunny winters, reflective board insulation on the north wall can reduce heat loss up to 10%. However, north wall insulation will reduce light levels, particularly in cloudy climates where much of the light received by the crop is reflected from clouds and the surroundings. Reduced light levels can delay plant development which might extend the growing season, therefore increasing heating costs.

Best Practices for Greenhouses - Insulation

Minimum Standards & Recommendations

Foam board insulation should be 1" to 2" thick and foundation wall insulation should extend from about 24" below grade up to plant height. Select insulation with a high R-value for greater energy and cost savings.

All insulation should be waterproofed with a vapor barrier and covered with aluminum foil laminate or galvanized steel to minimize fire hazard. The aluminum foil protects the foam from UV deterioration and reduces fire hazards. Interior insulation can help reflect direct solar radiation back to the plants. Spray-on foams can also be used on framed walls and should be protected. Outside insulation should be completely weatherproofed. Install sealed doors that have a U-value of 0.30 or less.

Energy Savings

Energy savings will vary based on the thickness and R-value of the insulation installed and the heat loss throughout the entire greenhouse. R-values can be added together to determine the potential loss of heat flow with insulation. For instance, one inch of polyurethane board insulation with an R-value of 4.0 added to a concrete foundation (R = 1.3) increases the R-value to 5.3 and reduces heat losses by 75%.[iv] It is possible to save 400 gallons of fuel oil per year by applying 2" of foam insulation to a 3' high kneewall on a 28-foot by 100-foot greenhouse.[v] (Note: U-value = 1/R. U-value and R-value cannot be added together to determine heat loss reduction.)

Environmental Impact & Benefits

The energy savings achieved by installing sidewall and endwall insulation will result in a reduction of greenhouse gas (GHG) emissions, reducing the environmental footprint of the greenhouse.

Economic Benefit

Estimated cost of implementation:
Two inch thick foam perimeter insulation costs approximately $1.50 per linear foot of insulation installed. A 4' wide insulation board should insulate 24" up the wall and 24" below ground.

Estimated Payback:
Payback will depend on installation costs and the efficiency and run time of the greenhouse heating system. A 28-foot by 100-foot double IR-poly film Quonset greenhouse has a potential savings of $1,150 by insulation sidewalls with 2" foam board insulation. Considering a project cost of $1,280 ($5/linear foot installed) for excavating and insulation installation, the payback would be 1.1 years. Based on audits completed in Massachusetts, most paybacks were less than 2 years, and often less than one year.

Best Practices for Greenhouses – Thermal Blankets

Technology

Thermal Blankets/Energy Screens

At a Glance:

- Savings up to 40% of heating fuel needs
- Paybacks in as little as 2 years with incentives, and 4.6 years without
- Have dual purpose as shade cloth and off set ventilation cooling needs in summer

Description of Best Practice

About 85% of greenhouse heating occurs during evening hours. Thermal blankets may be drawn above plants and heating outlets in a greenhouse to decrease the volume of heated space, providing an insulation barrier and retaining 30% to 70% of night time heat loss. Thermal blankets may also act as shade curtains during summer months, saving ventilation energy. Thermal blankets may be constructed of polyethylene, spun bonded film, or aluminum foil materials. They can be programmed to close automatically when needed, using an electronic control system, or they can be manually closed.

Thermal blankets reduce radiant heat loss from plants and other objects. Aluminized materials (with aluminum-coated fiber) provide the best method for retaining radiant heat loss, as aluminum reflects radiant heat back to the greenhouse. Thermal blankets rated with the highest heat retention, around 70%, are typically non-porous. While non-porous blankets retain the most heat, they will not have the dual purpose of acting as a shade cloth and they will also collect condensation. Porous and semi-porous thermal blankets are available and rated to retain 30% to 65% of heat loss.

Applications & Limitations

Optimal installation time for thermal blankets is during greenhouse construction. Retrofitting is possible but may require re-routing of irrigation and heating outlets as well as creating sub-structures to hold hanging baskets, thermostats, fans and other ceiling-mounted objects. Consult with a professional greenhouse equipment supplier for ideas on ways to fit a thermal curtain into individual and gutter-connected greenhouse structures.

Manually controlled thermal blankets have the benefit of cheaper installation costs, but require daily labor and operation. For optimal energy savings and plant growth, blankets should be drawn at sunset and opened at sunrise to prevent nighttime heat loss and allow plants sunlight during daylight hours.

Thermal blanket materials may also be installed on sidewalls and end wall gables to prevent heat loss, in which case they are referred to as thermal curtains. It is recommended to install overhead thermal blankets first: since heat rises, heat loss through ceiling glazing is greater than heat loss through sidewalls.

Best Practices for Greenhouses – Thermal Blankets

Minimum Standards & Recommendations

Thermal curtains and blankets should be installed in a way that prevents chimney effect heat loss, or heat loss through gaps in blanket materials. It is recommended to install U-shaped blanket materials where blankets meet walls or other blanket materials to act as a tight-fitting closure and prevent heat loss.

It is recommended to open and close curtains at sunset and sunrise for optimal energy savings. This can be completed by either using an electronic control system or with dedicated labor. It is recommended to open thermal blanket systems slowly, about six to twelve inches every thirty seconds to allow air temperatures to mix above and below the blanket. This will result in a less dramatic change in greenhouse temperature and less stress to heating systems and plants.

Some growers find it beneficial to leave thermal curtains open during snowstorms to allow heat loss which prevents snow build up and stress to greenhouse structures. For maximum energy savings, a grower should try keeping the blanket closed during a snowstorm to see if snow actually accumulates before opening the thermal blanket.

Make certain that curtains are fire retardant. (Most curtains are woven with a firebreak material.)

Thermal curtains typically come with a 5-year warranty on blanket materials. Typical lifespan of a thermal curtain is 10 to 12 years, but can change according to greenhouse conditions.

Energy Savings

Energy savings will vary according to the type of thermal curtain installed as well as its ability to close off gaps that allow heat loss. For a thermal curtain rated to have 50% heat retention savings, closed every evening of the heating season, savings may be 40% of overall greenhouse heating fuel. For a thermal curtain rated to have 30% heat retention savings, overall heating needs may be reduced by about 25%.

Environmental Impact & Benefits

The energy savings achieved by installing thermal blankets will result in a reduction of greenhouse gas (GHG) emissions, reducing the environmental footprint of the farm.

Economic Benefit

<u>Estimated cost of implementation:</u>
Thermal blankets typically cost $2.50 to $3.50 per square foot installed, including professional installation. Total cost of installation will vary according to the type of installation, curtain type, energy rating, size, and potential retrofitting adjustments.

Estimated Payback

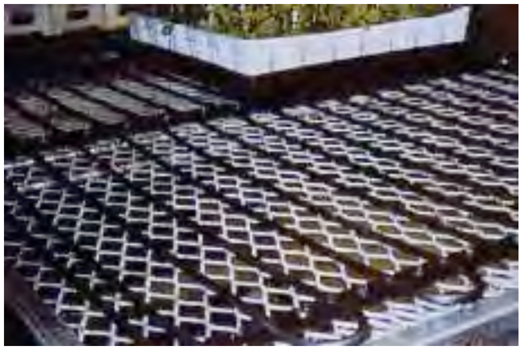
Based on energy audits performed on greenhouses in Massachusetts, paybacks can be as low as 2 to 5 years depending on heating requirements of the greenhouse, but can be much higher in greenhouses with limited heating needs.

A 28-foot by 100-foot double IR-poly film greenhouse heated through the cold seasons has the potential to save about $1,900 annually (at $2.50 per gallon of fuel oil) with the installation of a 50% energy-saving thermal blanket. Considering a thermal blanket cost of $8,000, the payback would be 4.4 years. Payback will range greatly depending on existing conditions and length of heating season. Based on audits in Massachusetts, paybacks have ranged from about 3 years to 15 years.

Best Practices for Greenhouses – Under Bench Heating

Best Practice

Under Bench / Root Zone Heating



Source: http://www.usgr.com/heating/heating.php

At a Glance:

- Up to 20% fuel savings by using hydronic heating
- Allows greenhouse temperatures to be reduced 5° to 15°F
- Existing boilers can be retrofitted to provide under bench heat

Description of Best Practice

Under bench heating provides heat under plant benches or within greenhouse floors for floor growing systems. By using under bench heating, the air temperature in the greenhouse can be set 5°-15°F lower than the soil temperature. In Northern climates, under bench or root zone heating may provide about 25% of the heating needs in the coldest conditions and all the heating needs during temperate spring and fall conditions.

Hydronic heating may be distributed under benches via flexible tubing, mats, or fin pipes. Water temperatures of 100° to 130 °F are typical for greenhouse hydronic heating. Forced air heating can be distributed under bench through ductwork or inflatable poly tubes. It is not as efficient as installing an under bench or root zone hydronic heating system, but it has been proven to be a cost-effective retrofit.

Applications & Limitations

Hydronic heating provides a radiant heat, which heats objects rather than air. Forced air under bench heating is not as common or as direct as hydronic heat. Forced air heating may make energy and economic sense if heat ducts can be re-routed from overhead to under bench. Unit heaters will require blower-style fans in order to provide enough force to move air through under bench air ducts.

Existing boilers may be retrofitted to route water under bench or in floor. In some retrofit cases a separate zone pump and mixing valve may be needed to lower existing boiler water temperatures. Tank-type water heaters may work well for providing under bench heating to single greenhouse or specific bench areas around 2,000 square feet. Consult with a heating professional for recommended water temperature settings and type of water heating, as this will vary according to hydronic tube layout, thickness of floor slab, and floor finish.

Overhead supplemental heating is often required to protect the upper plant and greenhouse area from low temperatures. Hydronic heating does not have an immediate response to temperature changes so the addition of an overhead heating unit may be necessary to provide immediate heat.

Best Practices for Greenhouses – Under Bench Heating

Geothermal, solar, wood, or biomass combustion may provide required water temperatures for under bench greenhouse heating. Careful consideration of renewable energy heat sources is advised, as these systems are not widely used and require specialized knowledge to predict feasibility and operational costs. Renewable heating systems typically cost more to install than a standard fossil-fuel heating system. A biomass combustion system requires labor for preparing and loading biomass fuel into the boiler. Also, solar and biomass systems may require a buffer tank to store hot water. Refer to the *Best Management Practices for Renewable Energy* for more information.

Minimum Standards & Recommendations

If purchasing a new boiler, it is recommended to purchase an Energy Star certified boiler (must have a minimum annual fuel utilization efficiency (AFUE) of 85%). A list of qualified units can be found on the Energy Star website. Choose a gas boiler with an AFUE rating of 90% or greater. A modulating unit can further increase efficiency by adjusting burner levels and heating according to the heating demand of the system. Older and less efficient boiler models fire at full capacity and often cycle on and off in an attempt to provide consistent heating. To properly size a boiler, research has shown that about 20 Btus per square foot of bench area is adequate to provide root zone heat without drying plants too much.

Boiler maintenance and servicing are recommended on an annual basis. The following is recommended during a tune-up: adjust and clean burners to maintain efficiency, calibrate thermostat, and check the feed water and wiring systems. Sediment issues with boilers are less of a concern because the system is closed loop (unlike tankless water heaters).

To minimize issues with new boiler units and to ensure validity of the warranty, have the unit installed by a professional. Most issues relating to high efficiency boilers have resulted from improper installations.

If using forced air for under bench heating, be sure to maintain and clean ductwork to keep it clear of mold and other residue. Complete yearly inspections and maintenance of forced air heaters to ensure they are working efficiently.

If using hydronic heating, be sure to select appropriate piping that is rated to handle the water temperature and corrosion. High-temperature EPDM tubing and PVC (if water is less than 130°F) are the most common materials. Keep pipes as short as possible to reduce friction and heat loss.

Make efforts to curb heat loss. It is recommended to use skirting, a weed barrier, or poly-film sheets 18” in height, around the perimeter of benches to retain heat to the root zone. It is also recommended to completely cover benches with plants to retain heat loss to the air. Greenhouses should be maintained by caulking and other air sealing methods, and should be insulated, such as with 2” foam board, up to bench height to prevent heat loss.

Best Practices for Greenhouses – Under Bench Heating

An electronic control system will help maintain greenhouse temperatures and control interaction between heating and ventilation events. Electronic temperature controls that include a weather station to anticipate ambient temperature drops may improve the response time of hydronic heating systems and prevent the less efficient, overhead heating from kicking on. Place thermostat at plant height and away from end walls.

Energy Savings

Energy savings will vary according to the efficiency of the existing versus retrofit system, the ability to lower thermostat settings, control system, and other heating system dynamics. Potential energy savings range up to 20%.

Environmental Impact & Other Benefits

The fuel savings achieved by installing under bench heating will result in a reduction of greenhouse gas (GHG) emissions, reducing the environmental footprint of the greenhouse

Economic Benefit

Estimated cost of implementation:
New boiler systems will range in price depending on size and installation requirements. Units typically range from \$2,500 to \$4,000 (not including installation) per high efficiency boiler depending on the BTUH rating It is recommended to obtain a quote for installation as it will vary based on the existing setup. Hydronic tubing equipment typically costs about \$1 per square foot of floor area covered, but this does not include installation or labor.

Comparison of operational costs and payback discussion:
Payback will vary according to the heat loss properties of the greenhouse. For example, an IR-double poly film 2,500 ft^3 Quonset style greenhouse will require about 345 MMBtu for overhead heating compared to 272 MMBtu for under-bench (with required fill-in overhead heating), a decrease of 73 MMBtu or 21%. This results in an annual savings of about 800 gallons of propane (525 gallons of fuel oil) or \$1,600 (based on \$2/gallon LP, or \$1,300 for fuel oil at \$2.50/gallon oil).

A 2,500 ft^3 single-pane glass gable style greenhouse will require about 776 MMBtu for overhead heating compared to 616 MMBtu for under-bench, a decrease of 160 MMBtu or 21%. This results in an annual savings of about 1,750 gallons of LP (1,150 gallons of fuel oil) or \$3,500 (based on \$2/gallon LP or \$2,800 for fuel oil at \$2.50/gallon oil).

The payback for each system will vary according to retrofit costs. If an existing boiler can be retrofitted, a payback less than 3.5 years is possible. If a new boiler is required to supply the under-bench heating, payback may be greater than 8 years. Due to a wide range of installed costs, it is recommended to have an energy audit completed and obtain a price estimate from a trade ally.

Best Practices for Greenhouses - Ventilation

Best Practice

Natural Ventilation / Efficient Mechancial Ventilation

At a Glance:

- Tight sealing louvers reduce heating costs
- Use climate controls to prevent ventilation while heaters are firing
- Proper maintenance can save 10-20%
- Natural ventilation may save more energy than mechanical ventilation

Description of Best Practice

Ventilation is used in greenhouses to maintain optimum temperature, humidity, and carbon dioxide levels for plant growth and health.[xi] Ventilation is required for all seasons and refers to changing inside air with air outside of the greenhouse. In summer, ventilation prevents the inside air temperature from rising too high above the outside air. The accepted minimum ventilation rate for summer is one air change per minute in order to maintain the temperature within a few degrees of the outside. In winter, ventilation removes moisture-laden air and helps eliminate condensation and other problems resulting from high humidities. The accepted ventilation rate for winter is generally two to three air changes per hour. Spring/Fall ventilation rates will be somewhere between the rates for summer temperature control and winter humidity control. Greenhouse ventilation can be achieved either by natural air movement or with mechanical fans.

Natural Ventilation

Due to increased concern over the high cost of energy to power mechanical fans, natural ventilation is again being emphasized. With proper design, orientation, and operation, natural ventilation can provide most of the required ventilation and use little to no energy. Natural air movement can be achieved with ridge and sidewall vents or roll up sidewalls. Natural ventilation conditions will vary by greenhouse design, location, season, and surrounding clearances. There are advantages and disadvantages to natural ventilation. (See the table below.) Consult with a greenhouse design professional to determine an effective natural ventilation strategy.

Advantages	Disadvantages
No need to purchase and replace exhaust fans	May not provide adequate cooling on hot, sunny days; additional cooling by evaporation may be necessary
Reduced energy costs	May be difficult to retrofit existing greenhouses
Reduced maintenance costs	Less control over management of air exchanges
Not dependent on electrical grid, reliable during outages	Not suitable for all greenhouse designs and locations

Best Practices for Greenhouses - Ventilation

Source: www.gothicarchgreenhouses.com

Ridge and Side Wall Vents

Ridge vents provide natural or passive ventilation and may reduce the need for mechanical ventilation because of thermal air movements and outside wind forces. They rely on a pressure difference created by wind and temperature gradients. Ridge vents require the presence of sidewall vents for air exchange; as greenhouse air heats, it rises through the ridge vent and is replaced by incoming air through side vents. Sidewall vents alone rely on outdoor wind to create suction of heated air through side vents. The combined sidewall vent area should equal the combined ridge vent area and each should be 15 to 20% of the floor area.[xii]

Roll-up sides

Roll-up sides can also be used for warm season ventilation to help offset the need for mechanical fans. There are both manual and motorized systems. It is important that the greenhouse be located in an area with good summer breezes and plenty of space between houses to provide air changes per hour, since this system does not rely on the thermal buoyancy of warm air as the ridge and sidewall vents do. It is recommended to determine the prevailing wind direction and average speed to determine if roll-up sides are a suitable option. The sidewall should be vertical up to the top of the attachment rail to prevent rainfall from entering.

During summer, a minimum of one air change per minute is recommended but may not be achieved on days without enough adequate wind. Horizontal air flow (HAF) fans create a pressure difference between inside and outside air conditions, and may be required for proper air flow through greenhouse vents.

Mechanical Ventilation

Mechanical ventilation requires fans, louvered inlet openings, and additional maintenance.

Fans

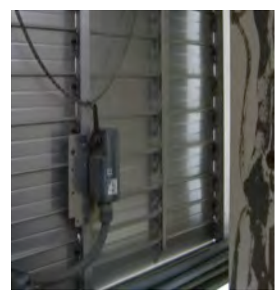
Placement and sizing of inlets are critical to the pressure difference which moves air for proper ventilation. Ventilation exhaust fans are usually mounted on one wall with matching inlets on the opposite wall. Fans promote evaporative cooling in the greenhouse.

Install enough fans so one air volume per minute is exchanged. Look for fans that provide a greater cfm/watt at 0.1 static pressure. Large diameter fans are more energy efficient than smaller fans. For instance, a 36” fan with a 1/3 horsepower motor can provide the same output as a 30” fan with a 1/2 horsepower motor while saving 180 watts per hour. Undersized fans do not effectively control the environment; however, oversized fans cost more to operate and create excessive air velocities which can negatively impact plant development. Install the largest diameter fans with the smallest motors that provide the required amount of ventilation.

Purchase fans that have been third party tested by Bess Labs and perform at the top third of the market. Current recommended standards are greater than 17.1 cfm/watt tested at 0.10 static pressure for 36” fans and greater than 20.3 cfm/watt tested at 0.10 static pressure for fans 48” and larger. Additionally, it is recommended to ensure that the fan motor that was tested by BESS Labs is the one actually included as the motor for the fan system.

Multi-speed fans can provide additional energy savings by varying their rates to maintain temperature set-points compared to a constant speed fan that cycles on and off. Discharge cones can also increase energy efficiency by reducing the amount of back pressure on the fan. Cones can increase efficiency by 10 to 15%.

Louvers



Intake louvers, which are used to provide sufficient air intake for mechanical fans, should be 1¼ times the fan diameter. Fan louvers should be connected to the climate control system that controls the fans. Air flow should be over the plants as opposed to under-bench or in the ridge; the bottoms of the fans and louvers should be about three feet above ground.[xiii]

Lubricate louvers so they seal tightly to reduce air infiltration. A partially open louver may allow several air changes per hour. For example a 48” fan louver with 1” gaps can allow 23,000 Btu/hour of heat to escape. Seal around fans and vents to prevent air infiltration. Additionally, if fans are not used during the winter, openings should be covered with polystyrene to minimize air infiltration.

Maintenance

Annual maintenance of ventilation systems should include testing the belt tension, and checking the fans, motorized shutters, and the control system. Thermostats should be cleaned and calibrated to ensure accurate readings, and ventilation systems should be cleaned regularly as well. Maintenance can reduce fan energy use by 10-20%.

Best Practices for Greenhouses - Ventilation

Environmental Impact & Benefits

The energy savings and offset of electrical production achieved by implementing energy efficient mechanical ventilation or natural ventilation will result in a reduction of greenhouse gas (GHG) emissions, reducing the environmental footprint of the greenhouse

Energy Savings & Economic Benefit

Energy savings will vary based on the ventilation strategy, type and number of fans, climate, and temperature set points. Additionally, misting or shade curtains can be used in conjunction with fans to reduce the need for mechanical ventilation and increase energy savings. Due to the large range of ventilation strategies it is recommended to complete an energy audit to determine if any energy savings are possible.

Energy efficient fans can reduce operating costs. Testing from BESS Labs has identified a 100% difference in energy efficiency levels of two comparably sized fans. An energy efficient 48" fan with a 1 hp fan that runs 1,400 hours annually will use approximately 1,500 kWh, which costs $225 a year to run at $0.15/kWh. Operating cost would double with less efficient models. There is a potential annual savings up to $110 by replacing a poorly designed fan.

Greenhouse ventilation fans cost approximately $700 to $1,100 each. Natural ventilation systems vary in cost by design and complexity as well as the potential need for HAF fans and it is recommended to consult a greenhouse expert for more information.

Funding Opportunities for Massachusetts Farm Energy Projects: Efficiency & Renewables

Where to Start – Information & Resources

Massachusetts Farm Energy Program (MFEP)
MFEP provides technical assistance and funding referrals for farmers looking for financial resources to support energy efficiency or renewables projects. MFEP staff are up-to-date on the evolving funding opportunities and offer an initial one-stop shop for funding resources for farm energy projects. Contact MFEP staff at (413) 256-1607.

Farm Energy Discount Program
All **agricultural ratepayers** in Massachusetts enjoy a **mandated 10% reduction on their energy bills** for electricity and natural gas supplied by public utilities as a result of legislation enacted to restructure the utility industry. Individual and corporations that are "principally and substantially engaged in the business of production agriculture or farming for an ultimate commercial purpose" are eligible. The Massachusetts Department of Agricultural Resources (MDAR) is the state agency responsible for determining farm eligibility for the Farm Energy Discount. A two-page application is available at http://www.mass.gov/agr/admin/farmenergy.htm or contact Linda Demirjian, Office Manager, MDAR, at (6l7) 626-1733.

Massachusetts Department of Agricultural Resources (MDAR)
MDAR offers **energy related grant opportunities** through the Ag-Energy Grant Program in May-June each year, in addition to farm viability and business development grants that may consider energy projects as a component.

MDAR also offers **support for farms** interested in energy efficiency, conservation, and renewables through their renewable energy coordinator position. More information and technical resources are available at http://www.mass.gov/agr/programs/energy/index.htm. To discuss the technical aspects of proposed energy projects, contact Gerry Palano, MDAR Renewable Energy Coordinator at 617-626-1706 or Gerald.Palano@state.ma.us.

DSIRE - Database of State Incentives for Renewables and Efficiency
This online database provides up-to-date resources on financial incentives for renewables and efficiency projects from state and federal sources, many of which are applicable to farm businesses. Search the Massachusetts pages for more information at www.dsireusa.org.

Installers and Contractors
Independent equipment installers, dealers, and contractors are a good source of information related to financial incentives for energy projects. Particularly in the case of renewable energy, installers need to track funding programs and realistically estimate how they affect the payback period for the project in order to maintain a competitive advantage in their field.

Energy Efficiency Financial Resources

State Resources

Public Utility Energy Efficiency Programs
Customers of investor-owned ("public") utility companies pay into conservation, efficiency, and renewable energy funds and therefore have access to energy efficiency programs. These "public" energy conservation programs are regulated by the MA Department of Public Utilities. Typically utilities offer **energy assessments**, performed by employees or contractors, as well as **financial incentives** (cost-share) on cost-effective energy efficiency measures.

There are four investor-owned electric utility companies in Massachusetts: National Grid, NSTAR, UNITIL (Fitchburg Gas & Electric), and Western Massachusetts Electric Company. In addition, Cape Light Compact operates the regional energy efficiency program for the Cape and islands. Natural gas companies include Berkshire Gas, Columbia Gas of Massachusetts (formerly Bay State Gas), National Grid (formerly Keyspan Gas), and NSTAR. For contact information related to farm energy assessments and incentives, go to http://www.berkshirepioneerrcd.org/mfep/existing.php or call the Massachusetts Farm Energy Program.

Municipal Utilities
Customers that are serviced by the 40 municipal electric and gas utility departments in the state typically do not pay into conservation or renewable energy funds. Some municipal utility companies have developed fee for service audit programs. Contact your individual municipal utility company to see what programs are available.

Federal Resources

USDA-Rural Development's (RD) Section 9007: Rural Energy for America Program (REAP)
USDA-Rural Development administers competitive grants for energy efficiency and renewable energy projects at 25% of eligible project costs, as well as guaranteed loans, to farmers and rural small businesses. The Massachusetts Farm Energy Program offers informational sessions and grant writing assistance to farmers for applying to this program, in cooperation with Berkshire-Pioneer RC&D, the Massachusetts Woodlands Institute, and USDA-Rural Development. The annual application deadline is generally in the spring. For information, go tohttp://www.rurdev.usda.gov/rbs/farmbill/index.html or contact your local USDA-Rural Development Area Office.

Energy efficiency project applications to REAP require an energy assessment or audit, and renewable projects require technical reports from installers. MFEP offers technical and financial assistance for energy audits but farmers must apply for an audit prior to the REAP application announcement. In addition, MFEP strongly encourages producers to work on preparing the application during slower seasons on the farm.

USDA-Environmental Quality Incentives Program (EQIP)
Under the 2008 Food, Conservation and Energy Act the Natural Resources Conservation Service (NRCS) can provide eligible producers with program support through the Environmental Quality Incentives Program (EQIP) to implement cost-effective and innovative practices that improve air quality. Individuals, groups and entities who own or manage farmland, pastureland or non-industrial forest land are eligible to apply. Producers with an annual minimum of $1,000 of agricultural products produced and/or sold from their operation are eligible to apply. For 2009 EQIP provided funding for specific conservation practices related to anaerobic digestion, greenhouse energy screens and horizontal air flow, and cranberry auto-start systems. More information about EQIP can be found at: http://www.ma.nrcs.usda.gov/programs/airquality/index.html or contact your local NRCS office.

Renewable Energy Financial Resources

State Resources

Department of Public Utilities (DPU) Net Metering
Net metering for wind, solar and agricultural energy installations encourages public utility customers to install solar panels and wind turbines, by allowing them to earn credit on their electric bills if they generate more power than they need. Farms are also encouraged to install additional renewable technologies such as anaerobic digesters.) Under the Green Communities Act signed by Governor Patrick in 2008, utility companies must compensate their customers for up to 2 megawatts of excess electricity at the retail rate rather than the lower wholesale rate. Additionally, customers may allocate their credits to other customers. To find out how you can apply for net metering contact your local eligible utility (NGRID, NSTAR, WMECO or UNITIL), or work through your renewable energy installer.

Municipal utility customers planning to install a renewable energy project to produce electricity will need to contact their suppliers to review net metering and interconnection policies.

Massachusetts Clean Energy Center (MassCEC)
The Green Jobs Act of 2008 created the Massachusetts Clean Energy Center (MassCEC) to accelerate job growth and economic development in the state's clean energy industry. The Renewable Energy Generation division of MassCEC is responsible for supporting renewable energy projects throughout the Commonwealth.

MassCEC has awarded funds to hundreds of businesses, towns, and non-profits for feasibility and/or design and construction of solar panels, wind turbines, biomass systems, hydroelectric systems, and other clean energy systems. Contact MassCEC to learn about current programs like Commonwealth Wind and Commonwealth Solar at www.masscec.com or call (617)315-9355.

Renewable Energy Certificates (RECs)
RECs are a means by which the environmental benefits, also known as the renewable attributes, of energy production by eligible renewable energy technologies can be sold to retail electric suppliers (RES) who are required to buy a minimum amount of these attributes to meet Massachusetts' renewable portfolio standard (RPS) requirements. For more details regarding eligible technologies and how prices are determined, refer to the MA Department of Energy Resources (DOER).

Solar Renewable Energy Certificates (SRECs)
The SRECs program is a market-based incentive program to support the development of 400 MW of solar photovoltaic (PV) infrastructure across the Commonwealth. SRECs are a means by which solar energy producers can sell the environmental attributes of solar generation to public utilities which are required to buy a minimum amount to meet Massachusetts' renewables portfolio standard (RPS) requirements. The sale of these certificates allows for a consistent cash flow for a ten-year period.

State Resources (cont.)

Massachusetts State Tax Deduction
Businesses in Massachusetts may deduct from net income, for state excise tax purposes, the installed cost of renewable energy systems. See www.dsireusa.org or contact a tax consultant for more details.

Federal Resources

USDA-Rural Development's (RD) Section 9007: Rural Energy for America Program (REAP)
The Section 9007 of the 2008 Farm Bill provides funding for renewable energy systems and energy efficiency improvements. USDA-Rural Development administers these funds and offers competitive grants at 25% of eligible project costs, as well as guaranteed loans, to farmers and rural small businesses. The Massachusetts Farm Energy Program offers informational sessions and grant writing assistance to farmers for applying to this program, in cooperation with Berkshire-Pioneer RC&D, the Massachusetts Woodlands Institute, and USDA-Rural Development. The annual application deadline is generally in the spring. For more information, go to http://www.rurdev.usda.gov/rbs/farmbill/index.html, or contact your local USDA-Rural Development Area Office.

Business Investment Tax Credit (ITC) and American Recovery and Reinvestment Act of 2009 (ARRA)
The federal business energy investment tax credit available under 26 USC § 48, and expanded by the Energy Improvement and Extension Act of 2008 (H.R. 1424) in October 2008 and the American Recovery and Reinvestment Act of 2009 in February 2009, provides tax credits for a range of renewable energy projects, ranging from 10%-30% of the eligible costs of renewable energy projects.
Deadlines: Credit Termination Dates vary by technology, but are generally available for eligible systems placed in service before January 1, 2017 (with the exception of large wind 1/1/13 and biomass 1/1/14).

U.S. Department of Treasury Renewable Energy Grants
Instead of taking the energy investment credit (described above), a taxpayer can apply for a cash payment valued at 30% of the total system cost for solar and wind systems through the Department of Treasury (section 1603 Cash Payment). More information is available at http://www.treas.gov/recovery/1603.shtml.
Deadline: construction must begin by 12/31/2011

Federal Accelerated and Bonus Depreciation
Under the federal Modified Accelerated Cost-Recovery System (MACRS), businesses may recover investments in certain property through depreciation.

Next Steps

Reviewing the *Massachusetts Farm Energy Best Management Practices Guide* is the first step in reducing energy use and saving money. Below are some steps to keep in mind for successful energy management.

Steps to Successful Energy Management

1. ***Learn about energy conservation, energy efficiency, and renewable energy***
   Learning about your energy use and ways to reduce it or supplement it with renewable energy is the first step. There is much information available about reducing energy use as well as case studies of farms that have taken action.

2. ***Apply for a farm energy audit or renewable energy assessment***
   An energy audit can help determine where energy is being wasted by inefficient equipment and practices and can recommend solutions. After reading about the MFEP Audits & Incentives Program on the Berkshire Pioneer RC&D website, complete an application to apply for an energy audit or renewable energy assessment. The link to the application is: www.berkshirepioneerrcd.org/mfep/forms/application.php.

3. ***Apply energy conservation practices***
   The easiest and most cost effective method of achieving energy savings is through energy conservation. Energy conservation means using energy wisely and eliminating energy waste, such as running a heater or a ventilation fan when it's not necessary.

4. ***Apply recommended energy efficiency practices***
   Energy efficiency means using less energy to produce the same end result. This manual focuses on conventional energy efficiency measures using current applicable technology. Energy efficiency measures should be taken before considering renewable energy. Reducing the amount of energy used is more cost effective than purchasing renewable energy to power inefficient devices.

5. ***Focus on Time-of-Use management (for cost savings, if applicable)***
   With proper Time-of-Use energy management, it is possible for agricultural producers to reduce their energy bills. Load demands change dramatically throughout the day, but utility companies must have the capacity to provide enough electricity for on-peak demand (typically aligning with summer months and daylight hours). In order to spread out this peak demand more evenly over the 24-hour day, electric utility companies provide a Time-of-Use (TOU) pricing structure. In a TOU billing structure, kWh prices are increased during on-peak hours and are reduced during off-peak hours to encourage customers to change behavior by using energy intensive equipment outside of peak hours.

6. ***Installation of Renewable Energy***
   After the previous steps have been exhausted, renewable energy is the final step. Renewable energy has a much lower environmental impact than conventional sources of energy production and decreases the US dependence on a fossil fuel economy. It also helps stimulate the economy and create job opportunities. Money spent on renewable energy is spent on materials and staff that build and maintain the equipment instead of importing non-renewable fossil fuels. This manual focuses on solar thermal, photovoltaic, wind, and biomass. Other technologies include, but are not limited to, anaerobic waste digesters (biogas), geothermal, and hydro.

Disclaimers

- Mention of trade names and products is for information purposes only and constitutes neither an endorsement of, recommendation of, nor discrimination against similar products not mentioned.
- Although this guide contains research-based information and the contributors have used their best efforts in preparing this guide, the contributors make no warranties, express or implied, with respect to the use of this guide. Users of this guide maintain complete responsibility for the accuracy and appropriate application of this guide for their intended purpose(s).
- In no event shall the contributors be held responsible or liable for any indirect, direct, incidental, or consequential damages or loss of profits or any other commercial damage whatsoever resulting from or related to the use or misuse of this guide.
- The contributors emphasize the importance of consulting experienced and qualified consultants, advisors, and other business professionals to ensure the best results.
- Project costs presented in this report are estimates only, based upon available pricing information at the time of compiling this report. Actual costs will likely vary due to many different variables.

Energy and Fuel Prices

Energy and fuel prices are constantly fluctuating. Actual prices will affect the economic feasibility of a project. The following energy prices have been used for purposes of the calculations throughout this manual:

- $0.15/kWh
- $1.10/therm
- $2/gallon propane (LP)
- $2.5/gallon fuel oil
- $200/full cord of wood (measured as 4’ x 4’ x 8’)

For more information, contact the Mass Farm Energy Program at Berkshire-Pioneer RC&D:
www.berkshirepioneerrcd.org/mfep or (413.256.1607

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